Hydrodynamics and Morphodynamics of Tidal Channels

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LONG-TERM GOALS

To measure, model, and understand the dynamics of currents, waves, and sediment transport over tidal flats, with particular emphasis on interactions between water flows and bathymetry.

OBJECTIVES

1. To measure water flows and bathymetric evolution within and around the tidal channels of Skagit Bay.
2. To explain the observed interactions between hydrodynamics and bathymetry.

APPROACH

We have used dense arrays of instruments, especially Acoustic Doppler Current Profilers (ADCPs), to measure flow fields within and near tidal channels. Multi-month deployments of fixed instruments measured the persistent flows responsible for bathymetric evolution. Repeated GPS surveys measured bathymetric evolution. Brief, intensive deployments of mobile current meters, CTDs, and drifters resolved hydrodynamic flow fields in greater detail.

Key individuals include Stephen Henderson (PI), Julia Mullarney (a Postdoctoral Researcher helping to coordinate fieldwork and undertake analysis), and Kassondera Dallavis (a Graduate Student contributing to fieldwork and analysis). Future work will analyze hydrodynamic measurements (this work will primarily fall to Julia Mullarney and Stephen Henderson), and test theories for morphological evolution (this work will primarily fall to Stephen Henderson and a to-be-appointed graduate student).

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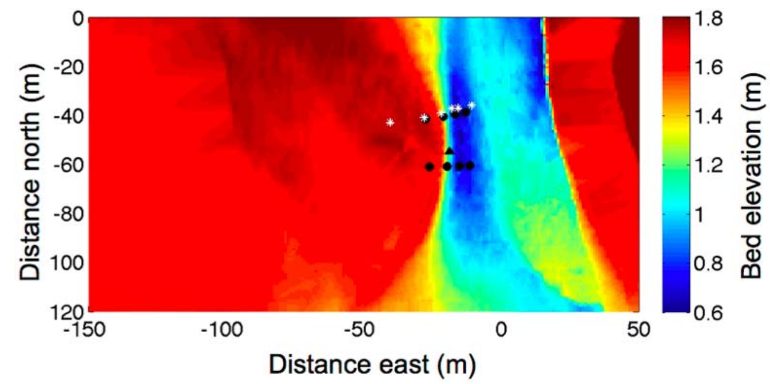

Figure One: Locations of fixed instruments during May (white stars) and June–August (ADCPs black circles, vertically-spaced CTDs black triangle). Color scale indicates bed elevation, with periodically-flooded tidal flats marked by red area, and permanently-flowing tidal channel marked by blue-green. [During May, six instruments were deployed in a single 40-m-long transect extending from tidal flats and across the curved western edge of a 40-m-wide, 1.2-m deep tidal channel which runs north-south. During June-August, two 4-instrument, 20-m-long transects crossed the channel-edge. These two transects were displaced by 20m in the along-channel direction.]

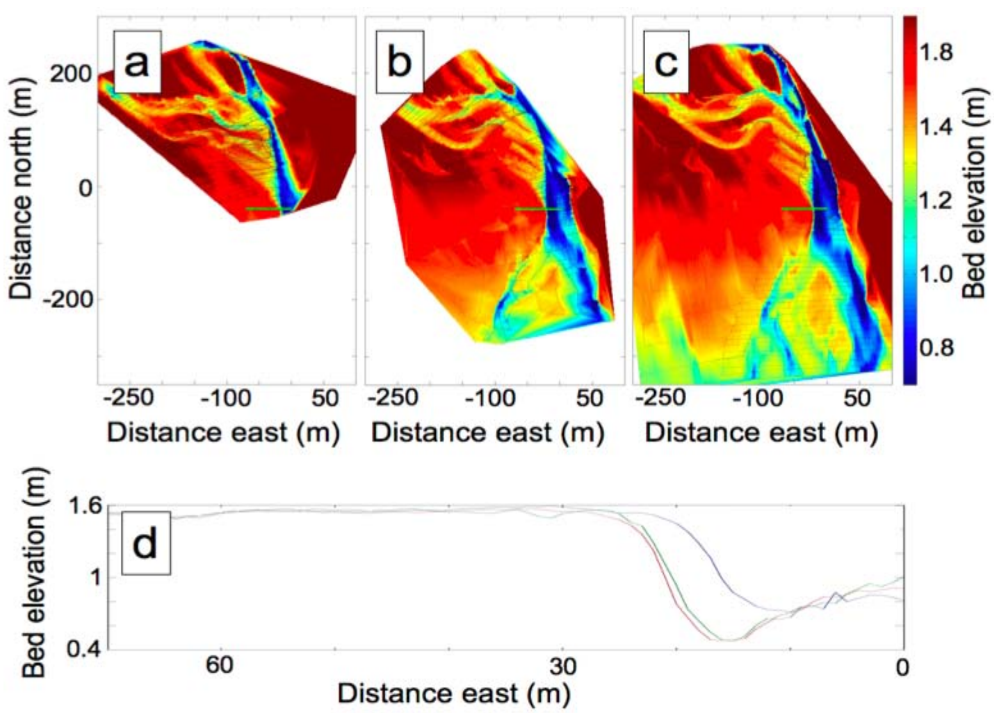

Figure 2: Bathymetric surveys for May (a) June (b) and July (c) 2009 (further surveys from Sept 2008, late July 2009, and August 2009 not shown). Cross-sections through surveyed channel edge bathymetry (d) for May (blue) June (green) and July (red) (location of cross-sections is indicated in (a)–(c) by green line).
[Repeated bathymetric surveys in a 300 m by 500 m region show a tidal channel surrounded by unmoving tidal flats. Cross-sections show that the channel edge moved about 10 m between May and June.]

WORK COMPLETED

Eight ADCPs, two CTDs, and 5 temperature gauges were deployed in Skagit Bay for 16 weeks during 2009. Two four-element across-channel ADCP transects measured flows near a curved channel-edge, while two vertically-offset CTDs measured stratification (figure 1). Six GPS surveys measured the bathymetric evolution of a tidal channel (figure 2).

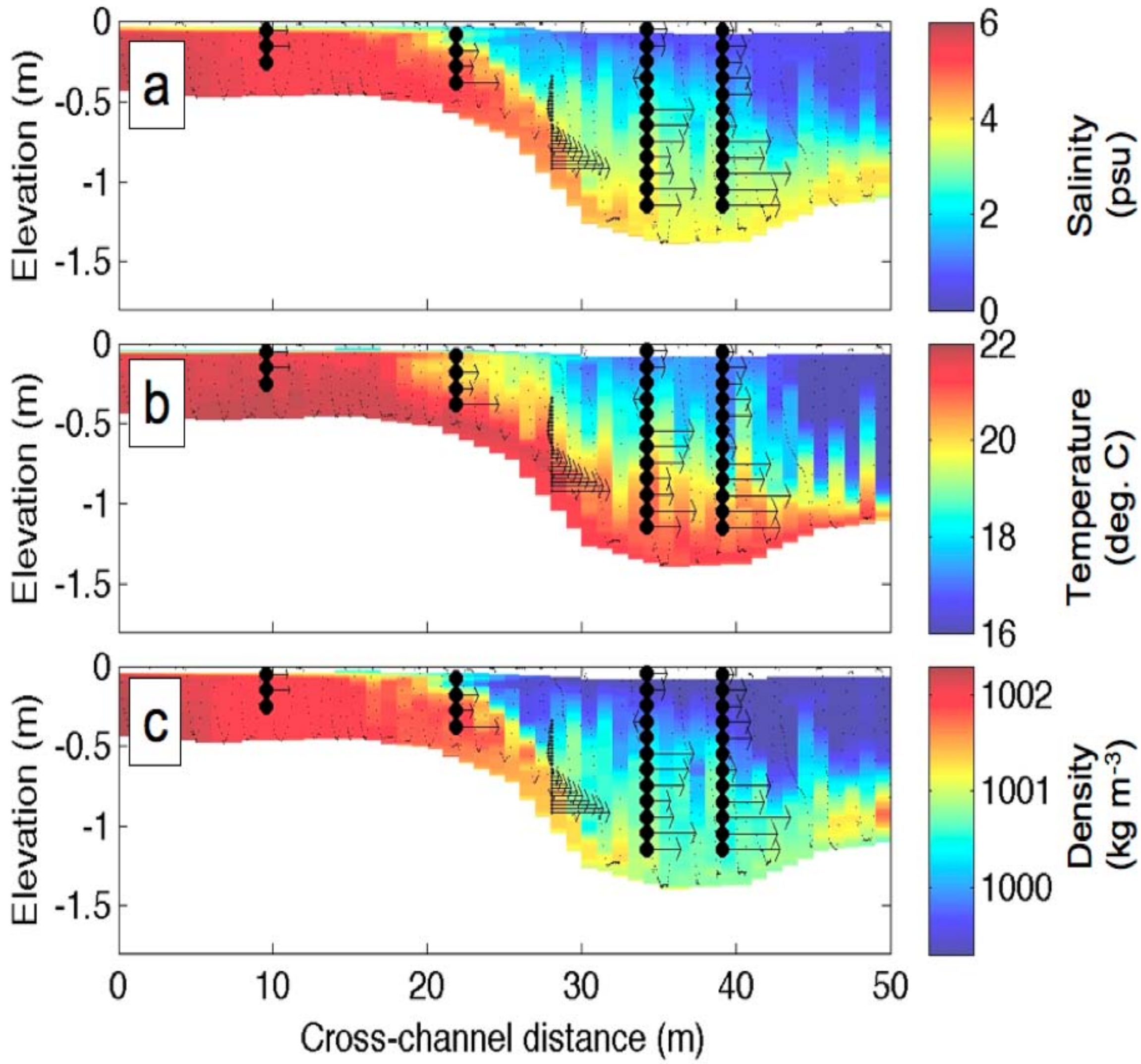

Figure 3: Sections through a channel-edge front of salinity (a), temperature (b), and density (c). Black arrows indicate cross-channel velocity measured by fixed ADCPs. Small black dots indicate locations of CTD measurements. Large black dots indicate locations of standard ADCP measurements. The velocity profile at cross-channel location 28 m was collected with a pulse-coherent ADCP. [Salty, warm, dense water over the tidal flats flows under fresher channel water and cascades down into the channel.]

During brief intensive deployments, mobile instruments measured spatial variability of flows in greater detail than possible with fixed instruments. Mobile CTDs measured salinity, temperature, and density (figure 3). Paired upward- and downward-looking Pulse-Coherent ADCPs cantilevered in front of a small boat measured water velocity (figure 4). In addition to mapping flows within channels, mobile instruments measured density fronts as they propagated across the tidal flats (30 transects were measured as one front propagated 1.7 km across the tidal flats), or were halted in propagation by a headwind (13 transects).

We deployed two ADCPs in Willapa Bay to support the efforts of other Tidal Flats DRI researchers (see related projects section below).

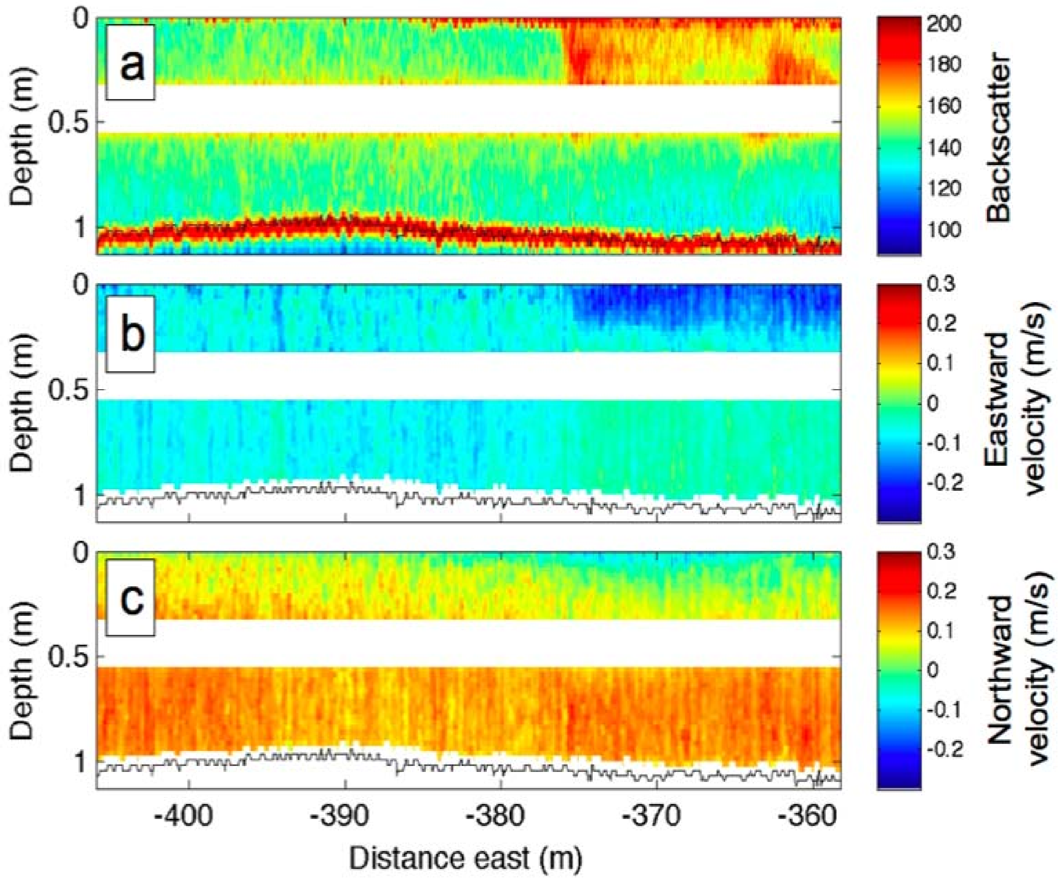

Figure 4: Sections across a westward-propagating front of acoustic backscatter intensity (a, arbitrary units), eastward velocity (b) and northward velocity (c). Black line indicates seabed. Distance east is measured in same coordinate as figures 1 and 2. Measured by upward- and downward-looking ADCPs cantilevered in front of a small boat at a depth of 0.45 m. Horizontal white band indicates data gap between upper and lower profiles. [High acoustic backscatter indicates a 50-cm-deep surface layer ending at a sharp surface front. Water velocity as function of depth and distance east shows 20-30 cm deep surface layer moving westward].

RESULTS

1. Intense baroclinic fronts were found to form on the edges of tidal channels during the early stages of flood tide (figure 3). A likely physical mechanism for front trapping (internal hydraulic control associated with across-channel currents) has been identified. The strongest near-bed across-channel flows we observed were generated by these fronts, a fact potentially significant to channel bathymetric evolution.
2. Departure of fronts from channel edges as flood tide progresses can also be understood in terms of hydraulic control theory. Once released from the channel-edge, fronts can form the propagating boundary of thin (sometimes only 30-cm-thick) surface plumes, which can persist for hours, carrying river water across kilometers of tidal flats.
3. Substantial (order 10 m) tidal channel evolution occurs during summer floods.

IMPACT/APPLICATIONS

The fronts we measured are clear to remote sensors. Hydraulic control processes, which closely link frontal dynamics with bathymetry, may prove useful in the development of bathymetric inversion algorithms.

Buoyant plumes distribute river water and fine sediments. Observations of plume propagation and mixing provide an opportunity to improve understanding of mechanisms for transport of salt, heat, and fine sediment across tidal flats.

A long-term goal is the development of accurate models for sediment transport across tidal flats. Testing the ability of sediment transport models to predict bathymetric evolution observed on tidal flats may contribute towards this goal.

RELATED PROJECTS

Our project is a component in a wider Tidal Flats DRI. All our fixed data from 2008, and some from 2009, is already available to other Tidal Flats researchers (http://www.vancouver.wsu.edu/fac/steve_henderson/res.html), and we are working to post our remaining 2009 observations.

We plan to compare our in-situ observations of near-surface currents with the remote sensing observations of other researchers. We have passed our ADCP data to Arete Associates, to help them test their remote estimates of surface velocity. We also plan to work with Jim Thomson and Chris Chickadel of the University of Washington, to improve understanding of tidal fronts.

In support of Tidal Flats researchers Tim Milligan, Paul Hill, and Brent Law, we have also measured currents in Willapa Bay. These researchers are now working to use these measurements to shed light on Willapa Bay sediment transport processes.